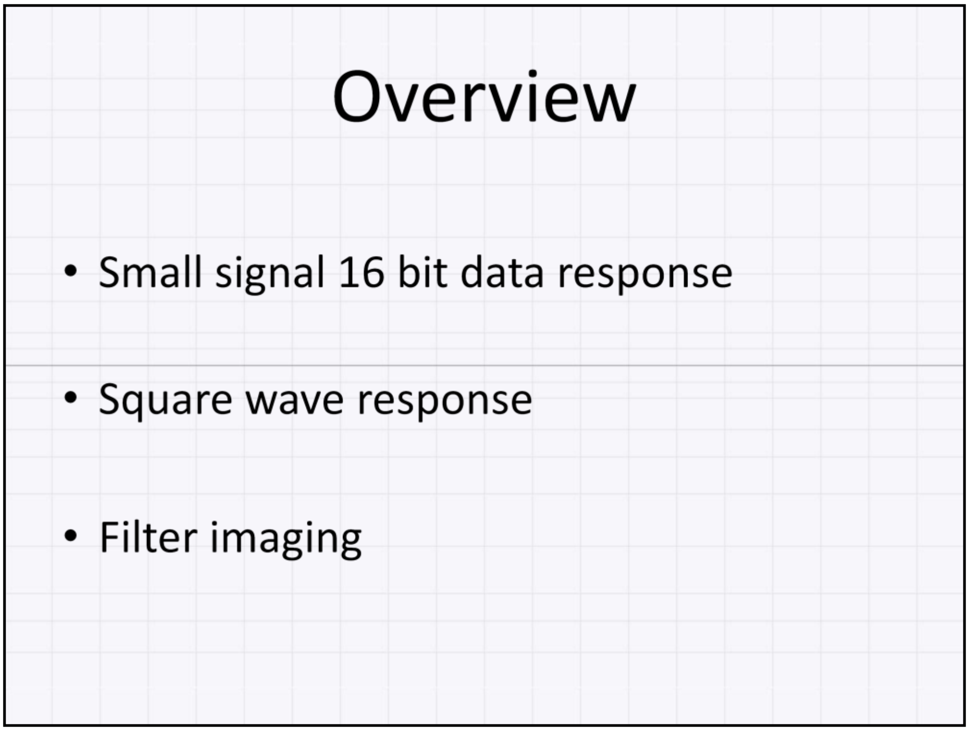
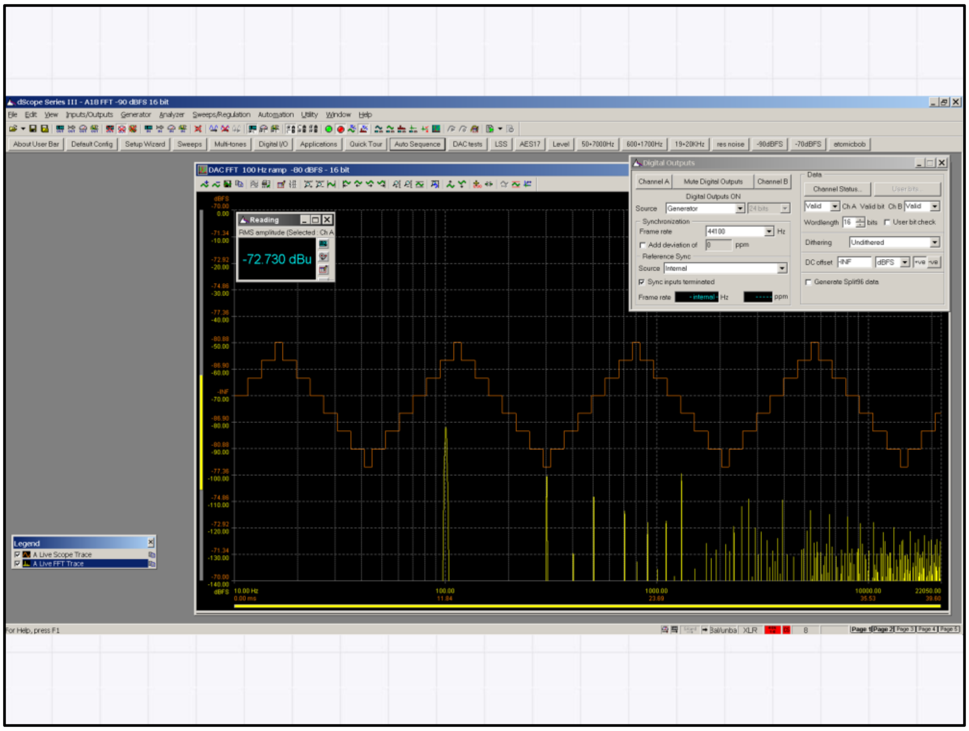
DAC Bandwidth
Measurement Considerations

Bob Smith

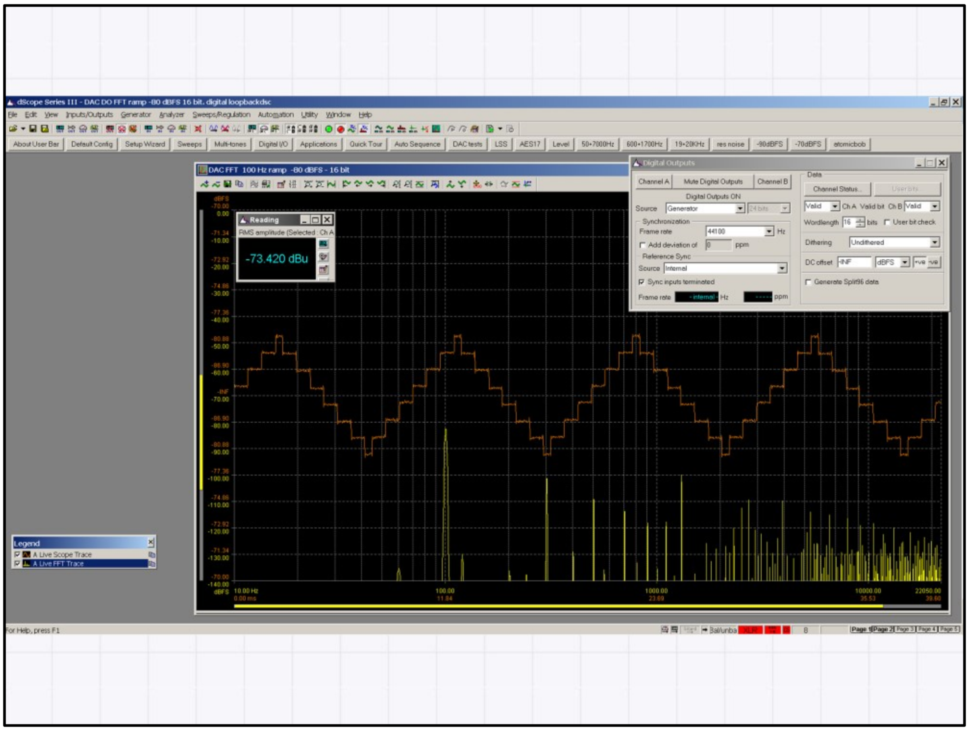
SoundSmith Labs



There are specific measurements where "stairsteps” may be observed, but the "edges" in the reproduced signal are band limited as will be demonstrated.
The following slides will show both the generator stimulus, DAC response and how the results are still necessarily band limited.
Both small signal and large signal DAC output step response will also be shown.
Finally DAC output filter imaging is presented.

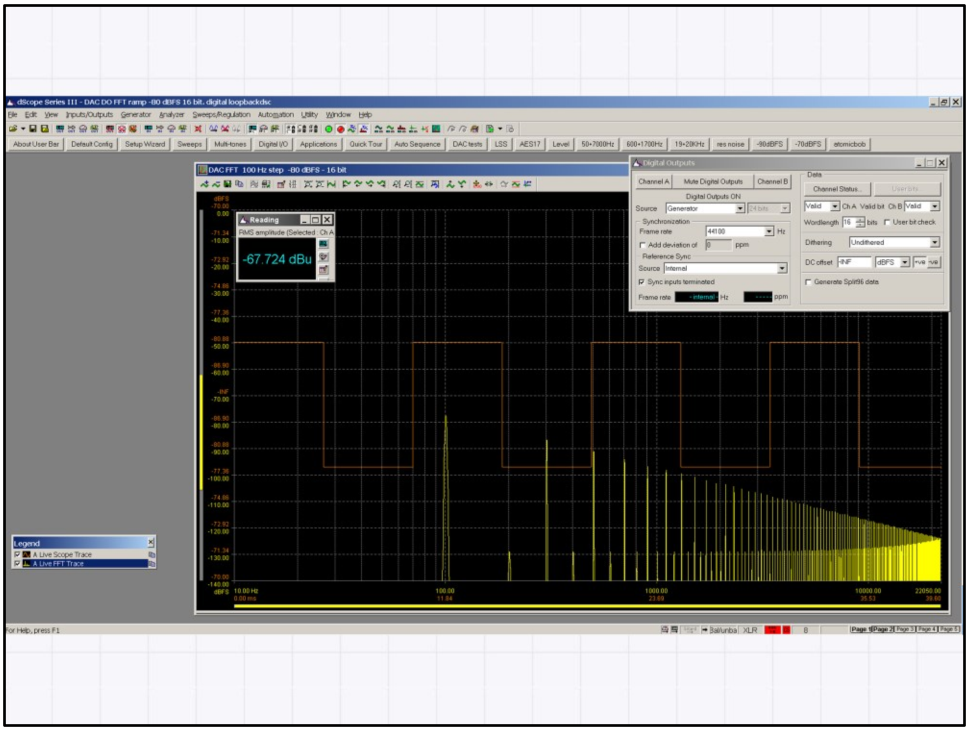


We will examine a 44100 Hz SR, 16 bit bit-depth system.
A 100 Hz, -80 dBFS triangle wave has 441 samples available distributed over 8 quantization levels for one cycle.
This graph depicts the 16 bit quantization level limited signal generator stimulus 100 Hz triangle wave presented in both time and frequency domain.
Observe what appears to be stair steps due to allocation of many samples at each of the quantization levels to follow a triangle wave profile.

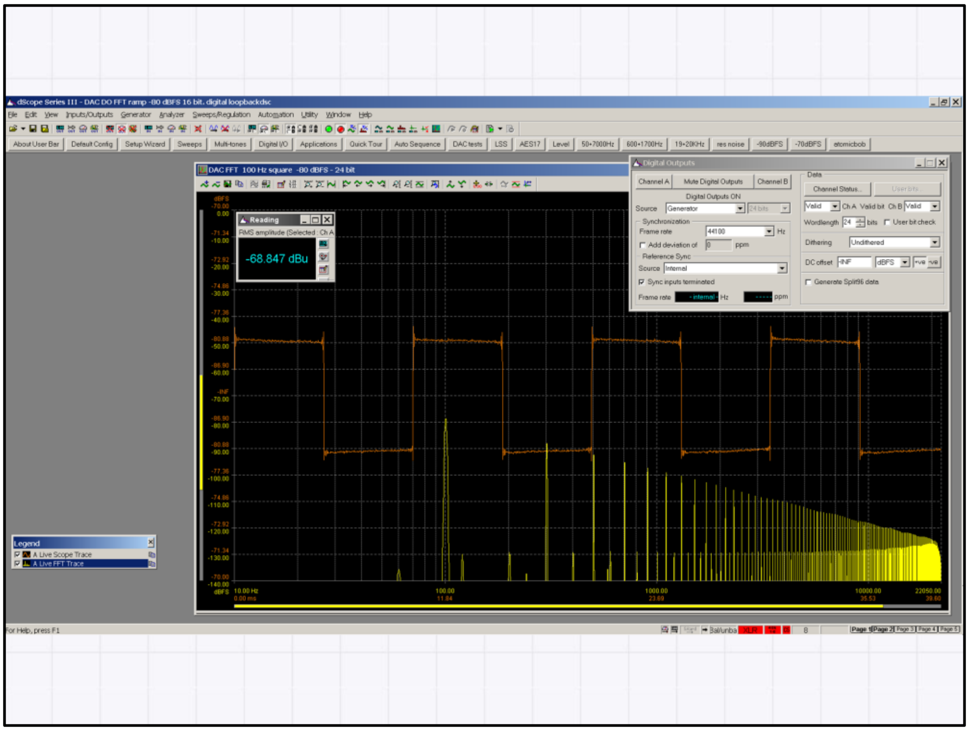


Here is the DAC output response to the stimulus in the previous slide. This DAC is capable of DC response. At very small signal levels we may observe the quantization level accuracy. DAC small signal response to 16 bit quantization level triangle wave stimulus appear to have stairsteps.

A close look at transitions reveals the change between levels takes a finite amount of time and is band limited by the DAC recovery filter. In the next several slides, examining step response will allow direct measurement of the level change rise time characteristics.



Changing generator stimulus to square wave for DAC small signal step response analysis.



This graph represents the DAC output response to small signal square wave input.

Bandwidth Estimation

$$BW \cong \frac{0.35}{t_r}$$

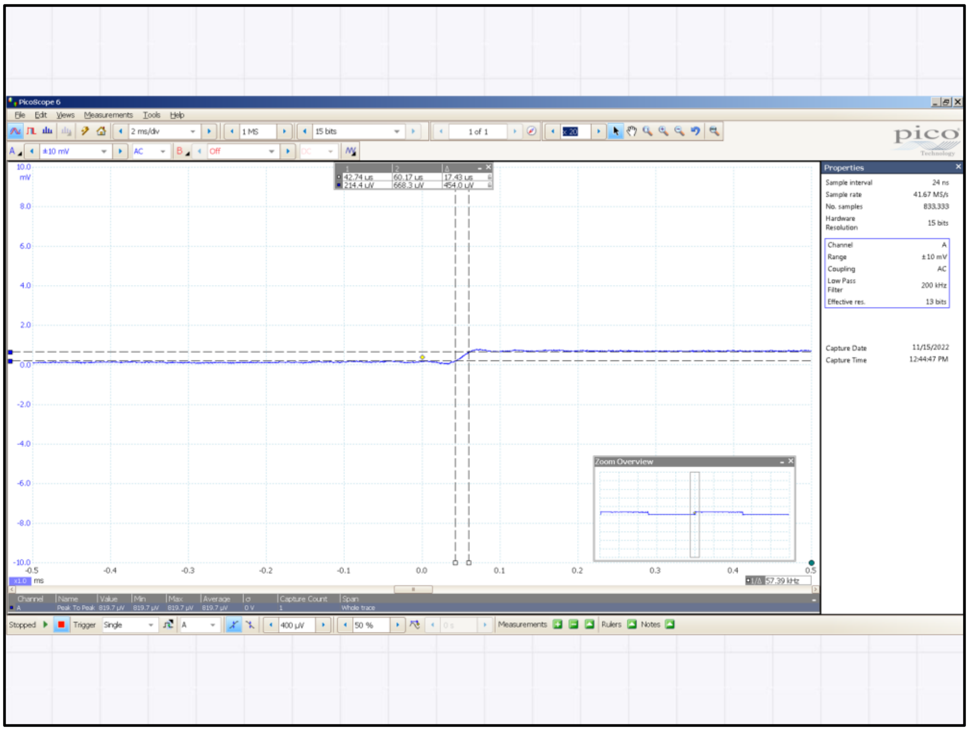
Where t_r = 10% to 90% rise time

https://www.edn.com/rule-of-thumb-1-bandwidth-of-a-signal-from-its-rise-time/

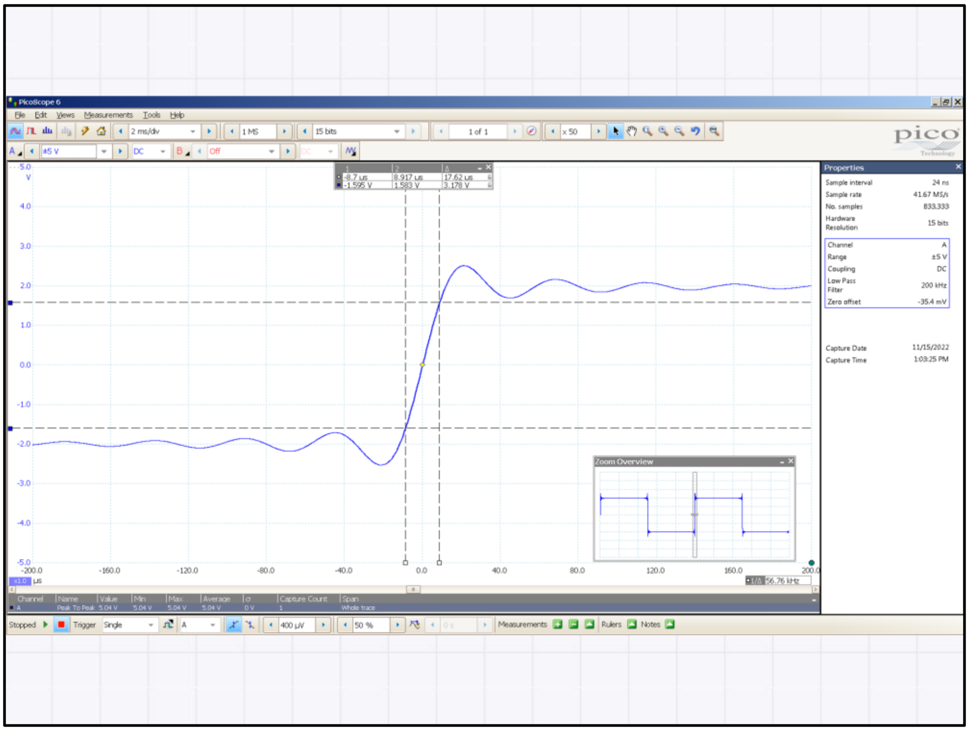
To estimate bandwidth requires measuring the 10% to 90% rise time and then using the Rule-of-Thumb formula:

BW (estimated) = 0.35 / RT

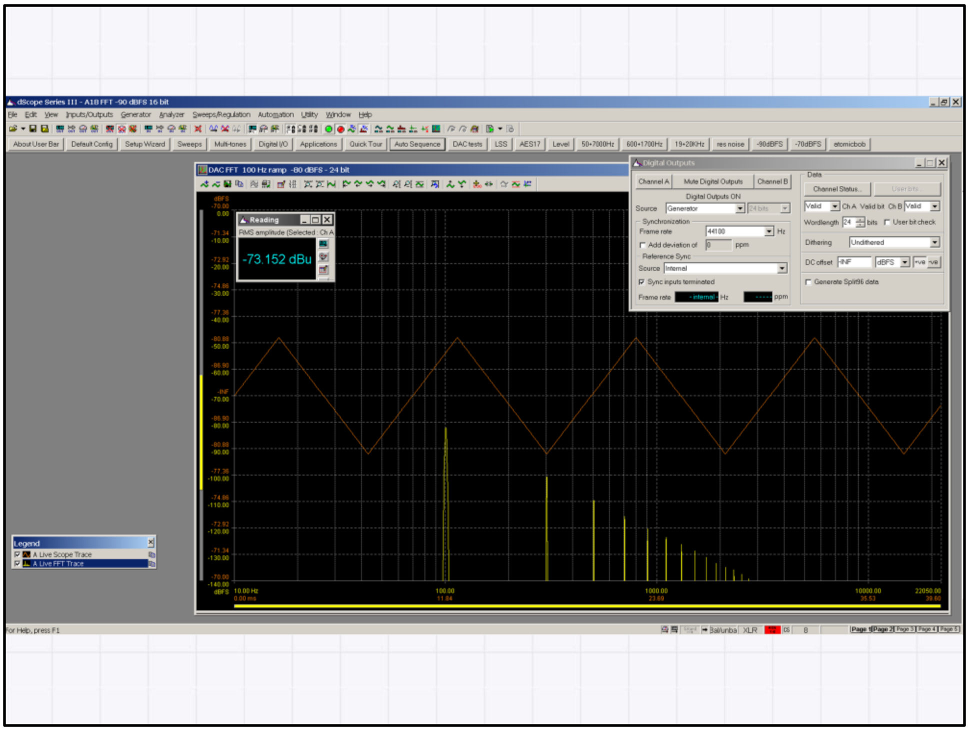
The factor 0.35 is from the first sine coefficient contribution in a Fourier Transform to create a square wave (A=2/(n*Pi)).



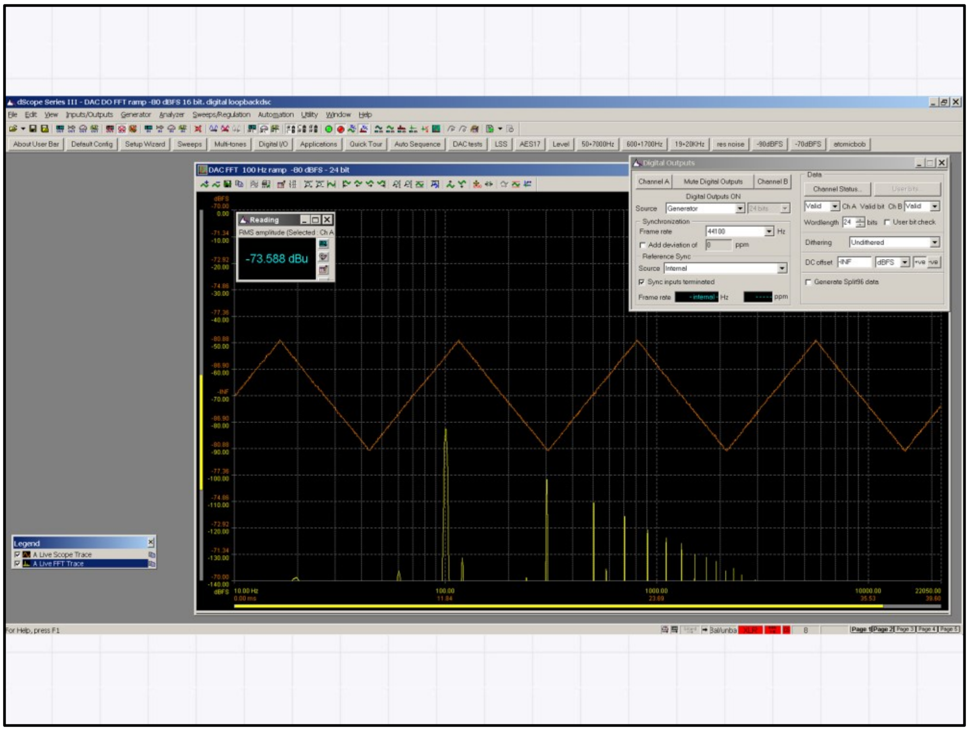
Oscilloscope measurement of the DAC small signal response to a step input (digital data square wave) at -80 dBFS.
Observe 10 to 90% rise time requires 17.43 uS.
BW (estimated) = 0.35 / RT
Here RT = 17.43 uS
Estimated BW = 20.1 KHz
No laws of physics or rules of digital audio have been violated.



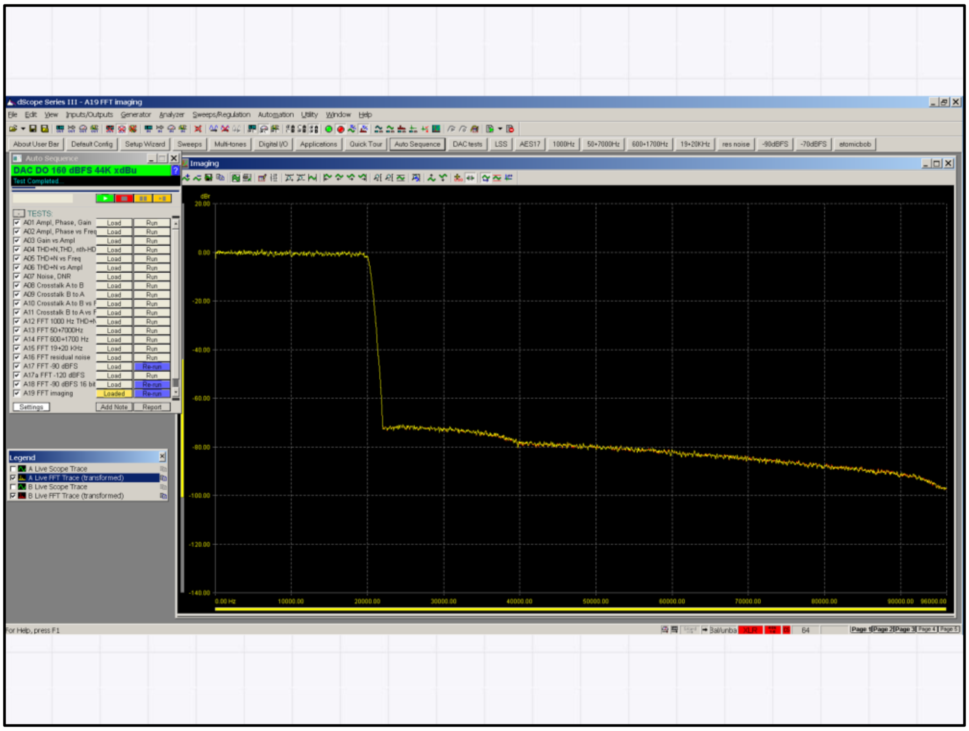
Increasing signal generator stimulus to -3 dBFS allows large signal analysis.
DAC output step response to digital input square wave.
To estimate bandwidth requires measuring the 10% to 90% rise time and then using the following Rule-of-Thumb formula:
BW (estimated) = 0.35 / RT
The factor 0.35 is from the first sine coefficient contribution in a Fourier Transform to create a square wave (A=2/(n*Pi)).
Here RT = 17.62 uS
Estimated BW = 19.9 KHz
Result is substantially similar to small signal response bandwidth previously observed.



This is the 24 bit quantization level limited signal generator stimulus 100 Hz triangle wave presented in both time and frequency domain.



DAC output with 24 bit quantization level triangle wave (small signal)



Example DAC imaging response with Sample Rate 44.1 KHz